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Shell Strength in *Corbicula* sp. (Bivalvia : Corbiculidae) from the Potomac River, Maryland

by

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Abstract. Forces required to crack intact shells of the freshwater Asiatic clam, *Corbicula* sp., were determined. They are higher than those which crack the wedge clam, *Rangia cuneata*, a globose, strong-shelled, oligohaline bivalve. Asiatic clam shell shape and strength may explain published data on crayfish predation on this animal in Oklahoma and Tennessee, in which predation was successful only on clams less than 6 mm in size or those with holes in the shell. Strong shells may also help prevent damage during periods of high river flow or strong water movement.

INTRODUCTION

Clams of the Asiatic genus *Corbicula* were apparently introduced to western North America early in this century, becoming widespread in the ensuing years (Britton & Morton, 1979; Counts, 1981). Recently, laboratory experiments by Covich *et al.* (1981) revealed that two species of freshwater crayfish were able to feed only on specimens of *Corbicula* that were less than 6 mm in size or that had damaged (perforated) shells. The Asiatic clam is globose in shape and the shell is relatively thick, giving the impression of strength. Mackie (1978) noted that the thickness of the shell of *Corbicula fluminea* was greater than the shells of 22 other species of sphaeriacean bivalves he investigated.

In an earlier study of crustacean predation on estuarine bivalves, we examined shell strength of eight species of clams (Blundon & Kennedy, 1982). Here we present measurements of shell strength of the Asiatic clam, compare them with the strength of the estuarine bivalves, and relate the results to the findings of Covich *et al.* (1981) concerning crayfish predation on *Corbicula*.

TAXONOMY of EXPERIMENTAL ANIMALS

There has been much confusion associated with the taxonomy of *Corbicula* in North America, with Britton & Morton (1979) having declared the species to be *Corbicula fluminea*. However, Hillis & Patton (1982) have presented evidence that two species of *Corbicula* (a "white form" and a "purple form") are present in the Brazos River, Texas. The specimens we tested in this report resembled the "white form" in color of nacre. Our specimens were collected from the Potomac River at Whites Ferry, Maryland (approximately 39°09′N; 77°31′W) in shallow water close to the river bank, a habitat in which Hillis & Patton (1982) found the "white form" to predominate. However, the mean number of growth rings ("annuli") for our sample was less than for the Texas sample and, when number of annuli was plotted against shell mass for each clam, all our values fell below the "envelope" surrounding the values that Hillis & Patton (1982) derived (their Figure 1) for the "white form" in Texas.

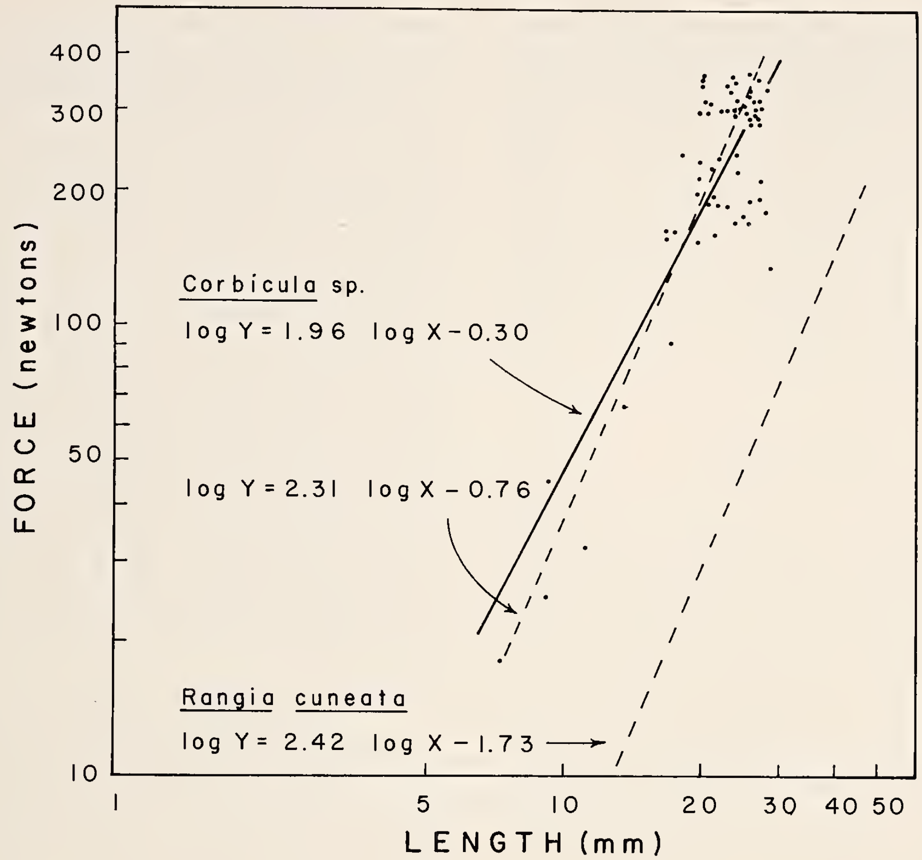

Figure 1

Predictive regression (——) and geometric mean functional regressions (-----) for shell strength of Asiatic clam (*Corbicula* sp.) and wedge clam (*Rangia cuneata*) from Maryland. Wedge clam data are from BLUNDON & KENNEDY (1982).

We agree with HILLIS & PATTON (1982) that the assignment of a species name to populations of *Corbicula* is unwarranted until conclusive taxonomic studies are performed; thus we have called our bivalves *Corbicula* sp. in this report. In referring to the reported work of others, we have kept the species names they used. Specimens from our study population have been deposited with the Smithsonian Institution's National Museum of Natural History (USNM 804414).

METHODS

To test for shell strength, we used an Instron testing machine, an industrial instrument that measures compression applied to a surface (BLUNDON & KENNEDY, 1982). Clams were crushed with a steel bar, 11 mm in diameter, which moved vertically downward at a velocity of 4 mm/s. Clams were crushed in the umbo region, parallel to the dorsoventral axis. A chart recorder was used to record force (in newtons) required to crack the clam shell. A 10-newton weight was used to calibrate the Instron before and during the experiment. Clams for crushing were collected from Whites Ferry and were crushed immediately upon return to the laboratory (within 2 h of collection).

RESULTS

Initially, $\log_{10}$ force (Y) was regressed on $\log_{10}$ length (X), length being the maximum anterior–posterior axis in mm, and a regression line ($\log Y = 1.96 \log X - 0.30$) was fitted (Figure 1). The coefficient of determination, R^2, was equal to 0.73 ($n = 70$). Because the measurements of force and size are subject to error of measurement, a geometric mean estimate of the functional regression may be a more appropriate linear regression (RICKER, 1973). The resultant equation (Figure 1) is: $\log Y = 2.31 \log X - 0.76$. This curve is significantly different from zero ($P < 0.001$).

As a comparison with these data, the geometric mean regression for *Rangia cuneata,* an oligohaline bivalve resident in Chesapeake Bay, is presented in Figure 1. *Rangia cuneata,* like the Asiatic clam, is a globose bivalve with a thick shell and closely fitting valves. It was the strongest bivalve we tested in our survey of shell strength of eight estuarine bivalves (BLUNDON & KENNEDY, 1982). However, the Asiatic clam had a stronger shell than did *R. cuneata* (Figure 1). The slopes of the geometric mean regression for the two species were not significantly different ($P > 0.05$), according to the test statistic of CLARKE (1980). However, the elevations of the two curves were significantly different ($P < 0.001$), as determined by Hotelling's T^2 (MORRISON, 1967).

DISCUSSION

As noted earlier, MACKIE (1978) found that the shell of *Corbicula fluminea* was the thickest of the shells of 23 species of sphaeriacean clams he studied. Neither MACKIE (1978) nor COUNTS & PREZANT (1982) present evidence that the shell of *Corbicula fluminea* is unusual in its structural material or in the arrangement of that material. In addition to shell thickness, the globose shape of the Asiatic clam, like *Rangia cuneata,* is probably an important reason for the crushing resistance being so high.

COVICH *et al.* (1981) noted that freshwater crayfish, *Procambarus clarkii,* attacked the edge of the shell of Asiatic clams with their mandibles. Repeated chipping of the shell led to eventual penetration. Such chipping away at shell edges should allow a relatively weak predator to open a strong-shelled bivalve. This chipping method was successful only with clams less than 6 mm long. Asiatic clams greater than 6 mm were successfully preyed upon by the crayfish *Cambarus bartonii* if the clams had suffered damage, such as perforations in the shell, which allowed the crayfish to reach their first walking leg into the soft clam body.

BROWN *et al.* (1979) found that a 33.7-g specimen of *Procambarus clarkii* could exert an average force of 9.9 newtons in the region of the base of the chelipeds, with force decreasing to 3.4 newtons near the tip of the chelipeds. The *P. clarkii* used by COVICH *et al.* (1981) ranged in size from 21.0–34.6 g, averaging 27.8 g. Using our geometric mean regression equation, we find that a 4-mm and 6-mm long Asiatic clam (respectively, the minimum and maximum size of undamaged prey that *P. clarkii* opened, according to COVICH *et al.,* 1981) have an average shell strength of about 4 newtons (4-mm clam) to 11 newtons (6-mm clam). Thus, if our data are transferable to southern clams, the crayfish used by COVICH *et al.* (1981) may not have been able to crush the Asiatic clams greater than 6 mm long, even if they had used their chelipeds in a crushing attempt (Covich *et al.* do not report any attempts by *P. clarkii* to use their chelae to crush shells). Theoretically, the larger crayfish (*e.g.,* 34.6 g) could crush the smallest (4 mm) clams available, assuming that the chelae could grip the globose shell appropriately.

With regard to other sources of shell damage that might leave Asiatic clams susceptible to crayfish predation, our clams were collected from a substrate of gravel and pebbles covered with silt, with cobble stones and boulders also present. Fast river flow during floods (*e.g.,* in spring) might cause substrate movement, with tumbling of clams or rocks and with grinding and pressure on shells. Strong shell structure would seem a useful protective measure under such conditions. COVICH *et al.* (1981) found damaged (perforated) shells in a rocky region of variable water flow below a dam. We have not noted much broken or damaged shell in our monthly surveys of Asiatic clams in our collecting area; most dead shell has consisted of intact valves.

We conclude that the thickness and globose shape of the shell of the Asiatic clam, which probably accounts for its considerable strength, should provide protection from predator crushing attack, especially for larger clams. This strength may also protect the clams in situations where they, or rocks, are being tumbled about in fast-flowing waters.

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